1-48

Microwave sounder cloud detection using collocated high resolution imager and its impact on radiance assimilation in tropical cyclone forecast

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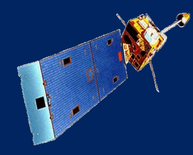


There are growing interests in the enhanced satellite data assimilation for improving Tropical cyclones (TCs) forecasts. Accurate cloud detection is one of the most important factors in satellite data assimilation due to the uncertainties of cloud properties and their impacts on satellite observed radiances. To enhance the accuracy of cloud detection and improve the TC forecasts, microwave measurements are collocated with high spatial resolution cloud products. The collocated measurements are assimilated for Hurricane Sandy (2012) and Typhoon Haiyan (2013) forecasts using the Weather Research and Forecasting (WRF) model and the 3DVAR-based Gridpoint Statistical Interpolation (GSI) data assimilation system. Experiments are carried out to determine cloud fraction and cloud top height thresholds to distinguish between cloud affected and cloud unaffected microwave radiances. The results indicate that the use of the high spatial resolution cloud products can improve the accuracy of hurricane forecasts by eliminating cloud contaminated microwave pixels. The methodology used in this study can be applicable to other advanced microwave sounders and high spatial resolution imagers for the improved TC track and intensity forecasts.

Methodology

Assimilation System and NWP Model

1. Gridpoint Statistical Interpolation (GSI):
- Unified variational data assimilation system for both global and regional applications
- Developed by NOAA NCEP based on the operational Spectral Statistical Interpolation analysis system.
- The core of the NDAS for NAM, GDAS for GFS at NOAA, and various operational systems.

2. Weather Research and Forecasting Model (WRF):
- Next-generation mesoscale numerical weather prediction system
- Developed by NCAR, NOAA, AFWA, NRL, OU, and FAA.
- Applicable for both meteorological research and numerical weather prediction.

3. Community Radiative Transfer Model (CRTM):
- Fast radiative transfer model for calculation of radiances for satellite IR or MW radiometers.
- Developed by JCSDA as an important component in the NOAA/NCEP data analysis system.
- Implemented into GSI system as its radiative transfer model.

Dataset for Assimilation System

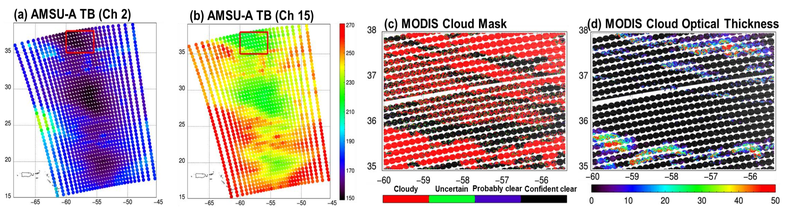
1. Advanced Mirowave Sounding Unit (AMSU)-A/Aqua:
- MW radiometer on Aqua platform with 15 channels from 23.8 to 89.0 GHz
- 49, 16 km spatial resolutions at nadir (Beam width: 3.3, 1.1°)

2. Advanced Technology Microwave Sounder (ATMS):
- MW radiometer on NPP platform with 22 channels from 23.8 to 183.3 GHz
- 45, 32, 16 km spatial resolutions at nadir (Beam width: 5.2, 3.3, 1.1°)

3. Moderate Resolution Imaging Spectroradiometer (MODIS)/Aqua Cloud Products:
- Cloud mask and cloud top height (CTH) at 1 km spatial resolution

4. Visible Infrared Imaging Radiometer Suite (VIIRS):
- Cloud mask at 750 m spatial resolution

5. WMO Global Telecommunication System (GTS) Data:
- Composed of surface observations, radiosondes, wind profiles, and aircraft data.

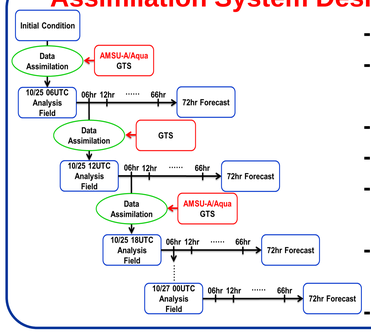


Experiments for Hurricane Sandy

Hurricane Sandy

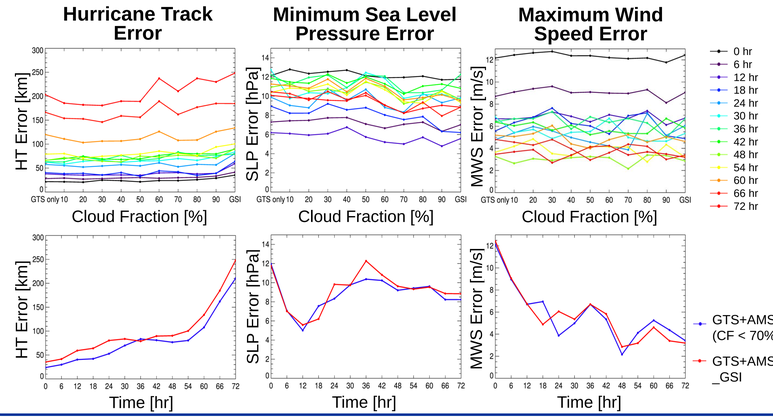
- Formed in the western Caribbean Sea on Oct. 24, 2012 and dissipated over Eastern Canada on Nov. 2, 2012.
- 147 direct deaths recorded across the Atlantic basin
- Preliminary U.S. damage estimates are near $50 billion.

Assimilation System Design

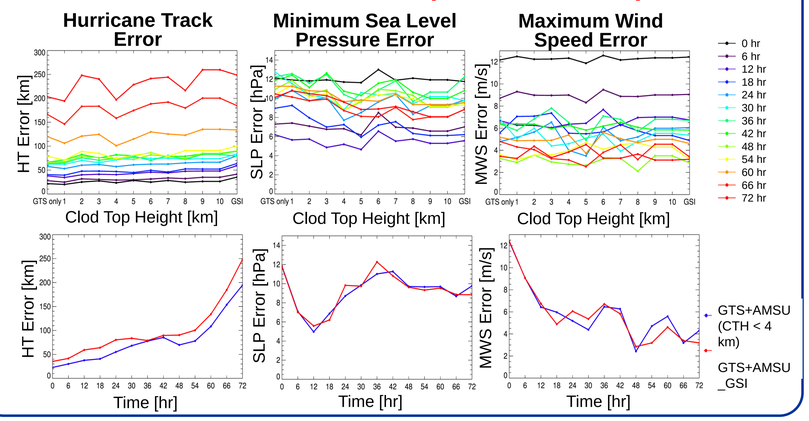


- **Domain:** 5N ~ 50N, 40W ~ 100W
- **Period:** 25 Oct, 2012 06UTC ~ 30 Oct, 2012 00 UTC
- **Forecast Running Time:** 72 hr (3 days)
- **Forecast Cycle Time:** 6 hr
- **AMSU Assimilation Time:** every 06 and 18 UTC
- **Initial and Boundary Data:** NCEP Final Operational Global Analysis data
- **Assimilation Window:** ±90 min

Forecast Results for Various Cloud Fractions (AMSU-A/MODIS)

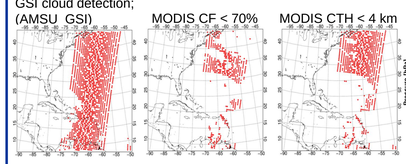


Forecast Results for Various CTH (AMSU-A/MODIS)



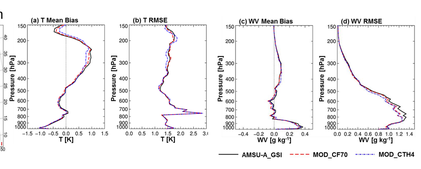
AMSU Data Coverage

25 Oct 06 UTC (54.4 GHz)

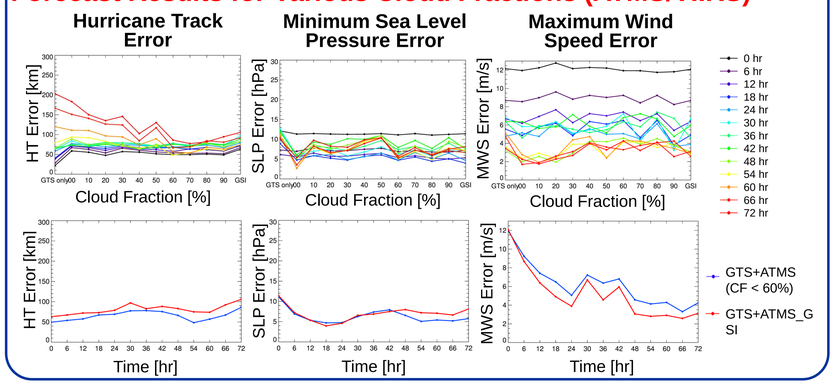


T/q Comparison with RAOB

72 hr forecast



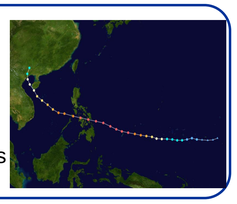
Forecast Results for Various Cloud Fractions (ATMS/VIIRS)



Experiments for Typhoon Haiyan

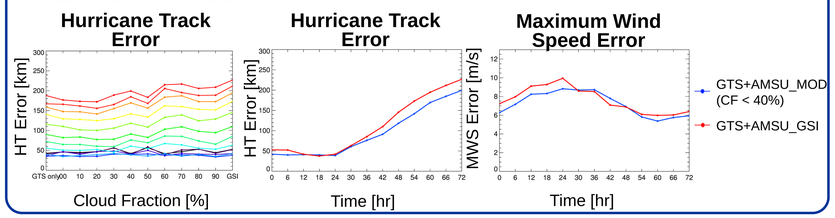
Typhoon Haiyan

- Formed over east-southeast of Micronesia on Nov. 3, 2013 and dissipated over Northern Vietnam on Nov. 11, 2013.
- The strongest typhoon recorded at landfall and 1-min sustained wind speed
- 6,300 deaths recorded in Philippines, and damage estimates are near $2.86 billion.

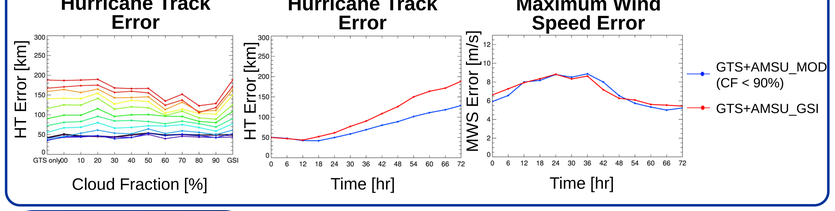


Forecast Results for Various Cloud Fractions (AMSU-A/MODIS)

- **Domain:** 5S~30N, 100E~160E; **Period:** 04 Nov 06UTC ~ 09 Nov 00 UTC
- **Assimilation window:** ±150 min



Forecast Results for Various Cloud Fractions (ATMS/VIIRS)



Summary

- MW measurements are collocated with high spatial resolution cloud products (CF and CTH), and then cloudy MW pixels are detected using various CF and CTH thresholds
- In order to investigate the impact of cloud contaminated radiances to TC forecasts, the collocated MW measurements are assimilated in WRF-GSI system.
- The results of this study suggest that the TC track and intensity forecast improved by taking advantage of high spatial resolution imager measurements.

References:

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- Li. J., W. P. Menzel, F. Sun, T. J. Schmit, and J. Gurka (2004), AIRS subpixel cloud characterization using MODIS cloud products, *J. Appl. Meteorol.*, 43, 1083-1094.
- Wang, P., J. Li, J. Li, Z. Li, T. J. Schmit, and W. Bai (2014), Advanced infrared sounder subpixel cloud detection with imagers and its impact on radiance assimilation in NWP, *Geophys. Res. Lett.*, 41, 1773–1780.